Posterior Multilevel Instrumentation of the Lower Cervical Spine: Is Bridging the Cervicothoracic Junction Necessary?

Osterhoff, Georg ; Ryang, Yu-Mi ; von Oelhafen, Judith ; Meyer, Bernhard ; Ringel, Florian

DOI: https://doi.org/10.1016/j.wneu.2017.04.029

Originally published at:
Osterhoff, Georg; Ryang, Yu-Mi; von Oelhafen, Judith; Meyer, Bernhard; Ringel, Florian (2017). Posterior Multilevel Instrumentation of the Lower Cervical Spine: Is Bridging the Cervicothoracic Junction Necessary? World Neurosurgery, 103:419-423.
DOI: https://doi.org/10.1016/j.wneu.2017.04.029

Posterior multilevel instrumentation of the lower cervical spine: Is bridging the cervico-thoracic junction necessary?

PD Dr. med. Georg Osterhoff [1,2], PD Dr. med. Yu-Mi Ryang [1], Judith von Oelhafen [1], Prof. Dr. med. Bernhard Meyer [1], Prof. Dr. med. Florian Ringel [1,3]

[1]Department of Neurosurgery, Klinikum rechts der Isar, Technische Universität München, Ismaninger Str. 22, 81675, Munich, Germany

[2]Division of Trauma Surgery, University Hospital Zurich, Rämistrasse 100, 8091 Zurich, Switzerland

[3]Department of Neurosurgery, Universitätsmedizin Mainz, Langenbeckstr. 1, 55131 Mainz, Germany

GO: georg.osterhoff@usz.ch

YMR: yu.ryang@tum.de

JVO: judith.vonoelhafen@lrz.tum.de

BM: bernhard.meyer@tum.de

FR: florian.ringel@unimedizin-mainz.de

Corresponding author:

PD. Dr. med. Georg Osterhoff
Division of Trauma Surgery,
University Hospital Zurich,
Raemistrasse 100
8091 Zürich,
Switzerland Tel.: +41 (0)44 255 56 57
Fax: +41 (0)44 255 44 66
E-mail: georg.osterhoff@usz.ch

Abstract

Background Multi-segmental cervical instrumentations ending at the cervico-thoracic junction may lead to significant adjacent segment degeneration. The purpose of this study was to compare the extent of sequential pathologies in the lower adjacent segment between patient groups with a primarily cervical instrumentation ending at C7 versus an instrumentation including the cervicothoracic junction ending at T1 or T2.

Methods A retrospective analysis of 98 consecutive patients with multi-segmental posterior cervical fusion surgery ending either at C7 or at T1 or T2 was performed. Radiographic parameters of degeneration at the adjacent segment below the instrumentation were determined postoperatively and at follow-up (FU), and the need for secondary interventions was documented.

Results Seventy-four patients had a FU of at least six months (C7: n=58, age 63±11, FU 36±26 months; T1/2: n=16, age 65±13, FU 37±21 months).

There were no significant differences between the C7 and T1/2 groups with regard to the change in kyphosis angle (p=0.162), disc height (p=0.204) or disc degeneration according to the Mimura grading system (p=0.718). Secondary interventions due to adjacent segmental pathology or implant failure were necessary in 18/58 (31.8 %) of the C7-cases and in 1/16 (6.3 %) of the T1/2-cases (p=0.038).

Conclusions Patients with multi-segmental posterior cervical fusions ending at C7 showed a higher rate of clinically symptomatic pathologiesat the adjacent level below the instrumentation. Based on our data and with its limitations in mind, one may consider to bridge the cervico-thoracic junction and to end the instrumentation at T1 or T2 in those cases.

Keywords cervical fusion; adjacent degeneration; revision; implant failure; cervico-thoracic junction.

Introduction

The prevalence of clinical adjacent segment pathology after cervical spine surgery has been reported to range from 1.6% to 4.2% per year with reoperation rates for clinical adjacent segment pathology around 0.8 % per year.[1] Especially multilevel cervical spine fusion constructs are associated with altered biomechanics and increased motion in the adjacent segments.[2, 3]

At the cervico-thoracic junction, the mobile cervical spine meets the rigid upper thoracic segments. In multi-level posterior cervical instrumentations ending at C7, this may lead to increased stress and, in consequence, to implant failure and adjacent segment degeneration.[4] Biomechanical studies have shown increased intradiscal pressures in the C7/T1 segment after multilevel instrumentation of the lower cervical spine.[5]

In line with this, cases have been described with C7 pars fractures sub-adjacent to C7 pedicle screw instrumentations.[6] Fusions adjacent to the lower end of the cervical spine are more prone to develop a clinically relevant adjacent segment pathology.[1]

Thus, it has been recommended in these cases to bridge the cervico-thoracic junction and to end the instrumentation at T1 or T2.[4-6]

The purpose of this study was to compare the rate of postoperative implant failure and the degree of distal junctional degeneration between patients with an instrumentation ending at C7 versus T1/T2.

Methods

The protocol of the present study was approved by the local ethics committee ([redacted]).

Consecutive patients who underwent posterior cervical instrumentation spanning more than three segments and ending either at C7 or T1/T2 between April 2007 and July 2014 were identified (n = 98) and retrospective chart reviews and radiographic assessments performed. Patients younger than 18 years of age, a follow-up period of less than 6 months, patients with paraplegia above the level of T2, and patients who had had previous posterior instrumentations ending at the cervico-thoracic junction or those with anterior fusion overlapping the cervico-thoracic junction were excluded. Previous anterior fusion within the interval of the posterior construct was not a reason for exclusion.

Surgery was performed by 7 different surgeons with expertise in spine surgery using a polyaxial screw-rod system. Patients were placed in a prone position. A posterior midline approach was performed with lateral mass or pedicle screws placed under lateral fluoroscopy. In order to support bony fusion, calcium phosphate bone graft granules (ACTIFUSE Microgranules, Baxter Deutschland GmbH, Bavaria, Germany) or a synthetic osteoconductive ß-tricalcium phosphate composite (chronOS Strip, Synthes GmbH, Oberdorf, Switzerland) were added. Patients were not required to wear a collar or cervical orthosis postoperatively.

For quantitative assessment of the radiographic degeneration at the segment adjacent to the lowest instrumented vertebra, the disc height, defined as the distance between the endplates' centers, and the mono-segmental sagittal Cobb angle were

measured on postoperative and follow-up radiographs and CTs (Figure 1). All measurements were performed by the first author using the digital calliper tool of a standard viewer software (Agfa Study Viewer 5.0.1, Agfa HealthCare, Mortsel, Belgium). Each measurement was repeated three times and an average value was computed.

In addition to quantitative measurements, disc degeneration at the lower adjacent segment was graded using a scale described by Mimura et al.[7, 8]

Primary outcome was the occurrence of a clinical relevant pathology in the segment adjacent to the lowest instrumented vertebra or implant failure in the most caudal instrumented segment. Clinical relevant adjacent segment pathology was defined as degenerative radiographic changes at this level with neck pain that required a secondary intervention (i.e. revision surgery, facet joint injections, and treatment with a cervical orthosis for more than a month). In 17 patients with insufficient clinical follow-up, we conducted telephone interviews to acquire additional information on symptoms and the need for secondary interventions as defined by the primary outcome.

Statistical Analysis

Statistical analysis was done by the use of SPSS for windows 21.0 (SPSS, Chicago, Illinois, USA). Nominal data was compared using Fisher's Exact Tests, and metric data was processed using the ANOVA for repeated follow-up measures and Mann-Whitney Test for comparisons between the two groups. Differences were considered significant for values of $p \leq 0.05$. Results are presented as means ± standard deviation.

Results

Seventy-four patients (age 64±12 years, 29 female) had a multilevel posterior cervical instrumentation with a clinical follow-up (FU) of at least six months (mean 37±24 months) and were included into the final analysis. There were 58 patients in the C7 group (age 63±11 years, 24 female, FU 36±26 months) and 16 patients in the T1/2 group (age 65±13 years, 5 female, FU 37±21 months).

The primary indications for posterior instrumentations were instability secondary to degenerative changes in 53 (71.6 %; C7: 79.3 %, T1/2: 43.8 %) cases, spondylodiscitis in 9 (12.2 %; C7: 8.6 %, T1/2: 25.0 %), traumatic spine fractures in 8 (10.8 %; C7: 5.2 %, T1/2: 31.3 %), and metastatic spine lesions in 4 (5.4 %; C7: 6.9 %, T1/2 0 %) cases. Ankylosing spondylitis was present in 4 patients (5.4 %; C7:5.2 %, T1/2: 6.3 %). The mean number of instrumented vertebrae was 5.2±0.9, range 4 to 8 (C7: 5.1±0.6, range 4 to 7; T1/2: 5.9±1.2, range 4 to 8). The mean duration of surgery was 179±57 minutes in the C7 group and 189±33 minutes in the T1/2 group (Mann-Whitney, $p = 0.159$).

Additional or previous anterior fusion surgery confined to the interval of the posterior instrumentation was performed in 39 patients (52.7 %), this accounted for 30/58 (51.7 %) cases in the C7 group and 9/16 (56.3 %) in the T1/2 group. The presence of previous anterior fusion did not have an impact on the occurrence of a clinical relevant pathology in the segment adjacent to the lowest instrumented vertebra (Fisher's Exact, $p = 0.120$).

Complete radiographic follow-up was available in a total of 52 patients (70 %), 44 of 58 (76 %) belonged to the C7 group and 8 of 16 (50 %) to the T1/2 group. There

were no differences with regard to the degree of disc degeneration according to the grading system described by Mimura et al [7, 8] (ANOVA, $p < 0.001$).

Most patients showed some degree of progressive radiographic degeneration at the adjacent segment below the instrumentation at follow-up with an increase in kyphosis angle (ANOVA, $p = 0.038$; Figure 2), a decrease of intervertebral disc height (ANOVA, $p = 0.066$) and a higher degree of disc degeneration according to the grading system described by Mimura et al [7, 8] (ANOVA, $p < 0.001$).

However, there were no significant differences between the C7 and T1/2 group with regard to the change in kyphosis angle (difference [Δ] C7 = 1.8±2.7°, Δ T1/2 = 0.4±1.9°; Mann-Whitney, $p = 0.162$), disc height (Δ C7 = -0.4±0.7 mm, Δ T1/2 = -0.1±0.5 mm; Mann-Whitney, $p = 0.204$) or disc degeneration according to the Mimura grading system (Δ C7 = 0.5±0.6, Δ T1/2 = 0.6±0.7; Mann-Whitney, $p = 0.718$).

With regard to the primary outcome, though, secondary interventions due to symptomatic lower adjacent segment pathology or caudal implant failure were necessary in 19/58 (31.8 %) of the C7-cases but only in 1/16 (6.3 %) of the T1/2-cases (Fisher's Exact, $p = 0.038$). Nine patients required surgical revision for a symptomatic pathology or implant loosening at the adjacent segment below the instrumentation (C7: 2 caudal extensions of the posterior instrumentation for bilateral screw loosening and 2 for painful segmental instability with progressive spinal stenosis, 3 posterior re-instrumentations for unilateral screw loosening, 1 antero-posterior re-instrumentation for bilateral implant loosening; T1/2 : 1 caudal extension of the posterior instrumentation for screw loosening)), in another four patients a surgical intervention was planned; solely a facet joint injection was performed in 3 cases, and three additional patients required long-term orthotic treatment. Of the 18 secondary interventions, 17

occurred in patients who initially had fusion surgery for degenerative instabilities and one in a patient with traumatic instability. No secondary interventions were necessary in patients who underwent posterior instrumentation for metastatic or infectious instabilities.

Three patients had revision surgery for reasons not related to the primary outcome, two had a wound revision for surgical site infection (both in the C7 group) and one had an anterior revision for a cerebrospinal fluid leak (in the T1/2 group). Patients with symptomatic adjacent segment pathology had a more pronounced increase in segmental kyphosis over time (2.6±3.1°) than patients who did not require a secondary intervention (1.0±2.2°; Mann-Whitney, $p = 0.050$). There were no significant differences among patients with or without clinical relevant adjacent segment pathology with regard to the change in disc height (Mann-Whitney, $p = 0.707$) or disc degeneration according to the Mimura grading system (Mann-Whitney, $p = 0.055$).

Discussion

The purpose of this study was to compare the rate of postoperative implant failure and the degree of distal junctional degeneration between patients with a multi-segmental cervical instrumentation ending above the cervicothoracic juntion (CTJ) at C7 versus one bridging the CTJ ending at T1/T2. Patients with multi-segmental posterior cervical instrumentations ending at the cervico-thoracic junction showed a higher rate of clinical relevant pathologies in the segment adjacent to the lowest instrumented vertebra than those with an instrumentation bridging the junction.

Previous biomechanical studies have suggested the presence of increased degenerative forces acting at the C7/T1 segment after multilevel instrumentation of the lower cervical spine. [4, 5] In their systematic review, Lawrence et al.[1] identified instrumentations ending at the lower cervical spine segments to be a risk factor for adjacent segment pathology, but did not include the cervico-thoracic junction itself into their considerations. The results of the present study are therefore well consistent with the published literature available.

In contrast, Kim et al.[9] observed no significant differences with regard to radiographic and clinical outcomes or the rate of revision surgeries in a cohort of patients after adult lumbar deformity fusion from the distal thoracic/upper lumbar spine to L5 or S1 when comparing three groups where the instrumentation either ended below, at or above the thoraco-lumbar junction. The change of segmental rigidity as found at the cervico-thoracic junction, however, may differ considerably from the situation seen at the thoraco-lumbar junction. In addition, the anatomical and biomechanical cervico-thoracic junction can always be located at C7/T1 while this is not true for the biomechanical thoraco-lumbar transition and T12/L1.[10-12]

At first glance, there is an obvious advantage of ending a multi-level posterior instrumentation at C7 instead of T1 or T2 in cases of lower cervical spine pathology: a short segment instrumentation represents a smaller intervention with fewer screws to be placed, theoretically less wound surface, and shorter operation time. In the present study the actual duration of surgery in the T1/2 group was only about 10 minutes longer than in the C7 group and this did not reach statistical significance. It is very likely, that the surgical time is merely determined by other factors as the extent of decompression. Due to the orientation of the pedicles of C7 and T1/T2 with a mean slope of T1 of around 25°,[13] the extent of the wound surface may not differ too much when the decision is made to bridge the cervico-thoracic junction. In fact, the only two revision surgeries for surgical site infection in this study were necessary in patients of the C7 group.

The limitations of this study are inherent with its retrospective study design and the lack of a precise matching of both groups. As radiographs of the whole spine were not available for most of the patients, this study did also not account for parameters of sagittal balance which may be of relevance when investigating adjacent degeneration. Although the study population comprises a sample of 74 patients, there were only 16 patients in the T1/2 group and the inhomogeneity of patients undergoing fusion surgery of the lower cervical spine may require prospective trials with larger samples. The indications for the primary posterior instrumentation differed between the two groups with more traumatic instabilities in the T1/2 group. However, 94 % of all secondary interventions occurred in patients who initially had fusion surgery for degenerative instabilities. Hence, it is very unlikely that the primary indication caused a relevant selection bias in this study.

This study did not account for parameters of sagittal balance of the cervical spine. As shown by Le Huec and others, one-third of the asymptomatic population has a cervical kyphosis.[14] It may be that the impact of a posterior multi-level instrumentation is increased in patients with cervical kyphosis (either idiopathic or post-fixation). So far, there is no data available in the literature, however, that suggests an increased vulnerability for adjacent degeneration in these patients. [1]

Even though all radiographic measurements were repeated three times, the sequential measurement of parameters like segmental kyphosis and disc height is always highly dependent on a similar radiographic projection and can be challenging at the cervico-thoracic junction. In addition, the availability of a full radiographic follow up was only 70 %. It is possible that the radiographic between-group differences in means did not reach statistical significance due to the small sample size. Even if they had been statistically different, though, one may question the clinical relevance in view of the small absolute differences. This accounts also for the statistically significant but most likely not clinically relevant difference in segmental kyphosis between patients with symptomatic adjacent segment pathology and patients who did not require a secondary intervention.

The primary outcome of this study was, however, not of radiographic nature but defined as the presence of symptomatic degenerative radiographic changes at the level adjacent to the lowest instrumented vertebra with the need for secondary intervention. It is debatable, if revision surgery, facet joint injections, and orthotic treatment over more than a month, all three per se secondary interventions, represent the same degree of harm to a patient. However, they are all an indirect sign for pain requiring intervention.

Most of the revision surgeries were caudal extensions of the posterior instrumentation. One could argue that bridging the cervico-thoracic junction during the index surgery would have saved these patients from a secondary intervention.

The increased need for these secondary interventions has to be weighed against the very theoretical risks of ending a multi-level posterior instrumentation at T1 or T2 instead of C7. This was confirmed by a very recent study showing that patients whose construct terminated at C7 were 2.3 times more likely to require a revision than patients whose construct terminated at T1. [15]

Conclusions

Patients with multi-segmental posterior cervical instrumentations ending at C7 showed a higher rate of clinically symptomatic pathologiesat the adjacent level below the instrumentation than instrumentations ending at T1 or T2. Based on our data and with its limitations in mind, one may consider to bridge the cervico-thoracic junction and to end the instrumentation at T1 or T2 in those cases.

References

1. Lawrence, B.D., A.S. Hilibrand, E.D. Brodt, J.R. Dettori, D.S. Brodke. Predicting the risk of adjacent segment pathology in the cervical spine: a systematic review. *Spine (Phila Pa 1976)*. 2012; 37(22 Suppl): p. S52-64.
2. Panjabi, M.M., T. Isomi, J.L. Wang. Loosening at the screw-vertebra junction in multilevel anterior cervical plate constructs. *Spine (Phila Pa 1976)*. 1999; 24(22): p. 2383-8.
3. Prasarn, M.L., D. Baria, E. Milne, L. Latta, W. Sukovich. Adjacent-level biomechanics after single versus multilevel cervical spine fusion. *J Neurosurg Spine*. 2012; 16(2): p. 172-7.
4. Kretzer, R.M., N. Hu, H. Umekoji, D.M. Sciubba, G.I. Jallo, P.C. McAfee, P.J. Tortolani, B.W. Cunningham. The effect of spinal instrumentation on kinematics at the cervicothoracic junction: emphasis on soft-tissue response in an in vitro human cadaveric model. *J Neurosurg Spine*. 2010; 13(4): p. 435-42.
5. Cheng, I., E.B. Sundberg, A. Iezza, D.P. Lindsey, K.D. Riew. Biomechanical Determination of Distal Level for Fusions across the Cervicothoracic Junction. *Global Spine J*. 2015; 5(4): p. 282-6.
6. Halim, A. and J. Grauer. C7 pars fracture subadjacent to C7 pedicle screw instrumentation at the caudal end of a posterior cervical instrumentation construct. *Am J Orthop (Belle Mead NJ)*. 2014; 43(7): p. E137-9.
7. Mimura, M., M.M. Panjabi, T.R. Oxland, J.J. Crisco, I. Yamamoto, A. Vasavada. Disc degeneration affects the multidirectional flexibility of the lumbar spine. *Spine (Phila Pa 1976)*. 1994; 19(12): p. 1371-80.
8. Quint, U. and H.J. Wilke. Grading of degenerative disk disease and functional impairment: imaging versus patho-anatomical findings. *Eur Spine J*. 2008; 17(12): p. 1705-13.
9. Kim, Y.J., K.H. Bridwell, L.G. Lenke, S. Rhim, Y.W. Kim. Is the T9, T11, or L1 the more reliable proximal level after adult lumbar or lumbosacral instrumented fusion to L5 or S1? *Spine (Phila Pa 1976)*. 2007; 32(24): p. 2653-61.
10. Lafage, V., F. Schwab, W. Skalli, N. Hawkinson, P.M. Gagey, S. Ondra, J.P. Farcy. Standing balance and sagittal plane spinal deformity: analysis of spinopelvic and gravity line parameters. *Spine (Phila Pa 1976)*. 2008; 33(14): p. 1572-8.
11. Roussouly, P., S. Gollogly, E. Berthonnaud, J. Dimnet. Classification of the normal variation in the sagittal alignment of the human lumbar spine and pelvis in the standing position. *Spine (Phila Pa 1976)*. 2005; 30(3): p. 346-53.
12. Roussouly, P. and J.L. Pinheiro-Franco. Sagittal parameters of the spine: biomechanical approach. *Eur Spine J*. 2011; 20 Suppl 5: p. 578-85.
13. Yu, M., W.K. Zhao, M. Li, S.B. Wang, Y. Sun, L. Jiang, F. Wei, X.G. Liu, L. Zeng, Z.J. Liu. Analysis of cervical and global spine alignment under Roussouly sagittal classification in Chinese cervical spondylotic patients and asymptomatic subjects. *Eur Spine J*. 2015; 24(6): p. 1265-73.
14. Le Huec, J.C., H. Demezon, S. Aunoble. Sagittal parameters of global cervical balance using EOS imaging: normative values from a prospective cohort of asymptomatic volunteers. *Eur Spine J*. 2015; 24(1): p. 63-71.

15. Schroeder, G.D., C.K. Kepler, M.F. Kurd, L. Mead, P.W. Millhouse, P. Kumar, K. Nicholson, C. Stawicki, A. Helber, D. Fasciano, A.A. Patel, B.I. Woods, K.E. Radcliff, J.A. Rihn, D.G. Anderson, A.S. Hilibrand, A.R. Vaccaro. Is It Necessary to Extend a Multilevel Posterior Cervical Decompression and Fusion to the Upper Thoracic Spine? *Spine (Phila Pa 1976)*. 2016; 41(23): p. 1845-1849.

Figure legends

Figure 1 Measurement of the mono-segmental sagittal Cobb angle

Figure 2 Case C7 group

Case of a 76-year old female patient who underwent antero-posterior decompressive surgery with posterior instrumentation from C3 to C7 for multi-segmental cervical spinal stenosis (A). the showed symptomatic adjacent degeneration at the level C7/T1 at the 1-year follow up (B) which improved temporarily after facet joint injection at this level.